Liquefaction Susceptibility Mapping at 1:24,000-scale, San Francisco Bay Area: Year 1

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Investigations Undertaken

The purpose of this study is to produce detailed Quaternary geologic maps to delineate areas susceptible to earthquake-induced liquefaction in the San Francisco Bay area. The products of our mapping project will consist of a series of sixty-eight 7.5-minute quadrangles located in high density population centers in the Bay area, including the cities of Berkeley, Fairfield, Hayward, Livermore, Petaluma, Richmond, San Jose, San Mateo, San Rafael, San Ramon, Santa Clara, Santa Rosa, and Walnut Creek (Figure 1). Examination of liquefaction susceptibility in the San Francisco Bay area is timely because urban expansion is encroaching on lands underlain by potentially saturated Holocene deposits and artificially filled land -- areas that have historically experienced liquefaction-related ground failure.

Damaging liquefaction occurred in the San Francisco Bay area during the 1868 Hayward earthquake, the 1906 San Francisco earthquake, 1983 Coalinga earthquake, and the 1989 Loma Prieta earthquake. These and other historical earthquakes show that the distribution of liquefaction-related ground failure generally is restricted to alluvial basins that contain shallow layers of low-density, saturated, granular sediment. If these conditions can be delineated, planners, government agencies, and individuals will be able to prepare for and mitigate the effects of liquefaction, and better prepare disaster response plans. For example, if local governments have information on areas of possible liquefaction hazard, they can require that site-specific analyses be performed prior to new development and appropriate engineering mitigation be incorporated into project design. The California Division of Mines and Geology (CDMG) plans to develop liquefaction zonation maps that local governments will be able to use for this purpose. Our proposed project will greatly facilitate and possibly accelerate CDMG's development of these maps.

The proposed map area has been targeted as high priority by CDMG for producing 1:24,000-scale liquefaction *zonation* maps. However, CDMG's program is not currently funded to produce detailed Quaternary geologic maps or liquefaction susceptibility maps of this area. We have collaborated with CDMG on past liquefaction mapping efforts and will provide data to CDMG at the level of accuracy and in the digital format required for their liquefaction zonation program. To accomplish this goal, we will revise maps that were produced for our

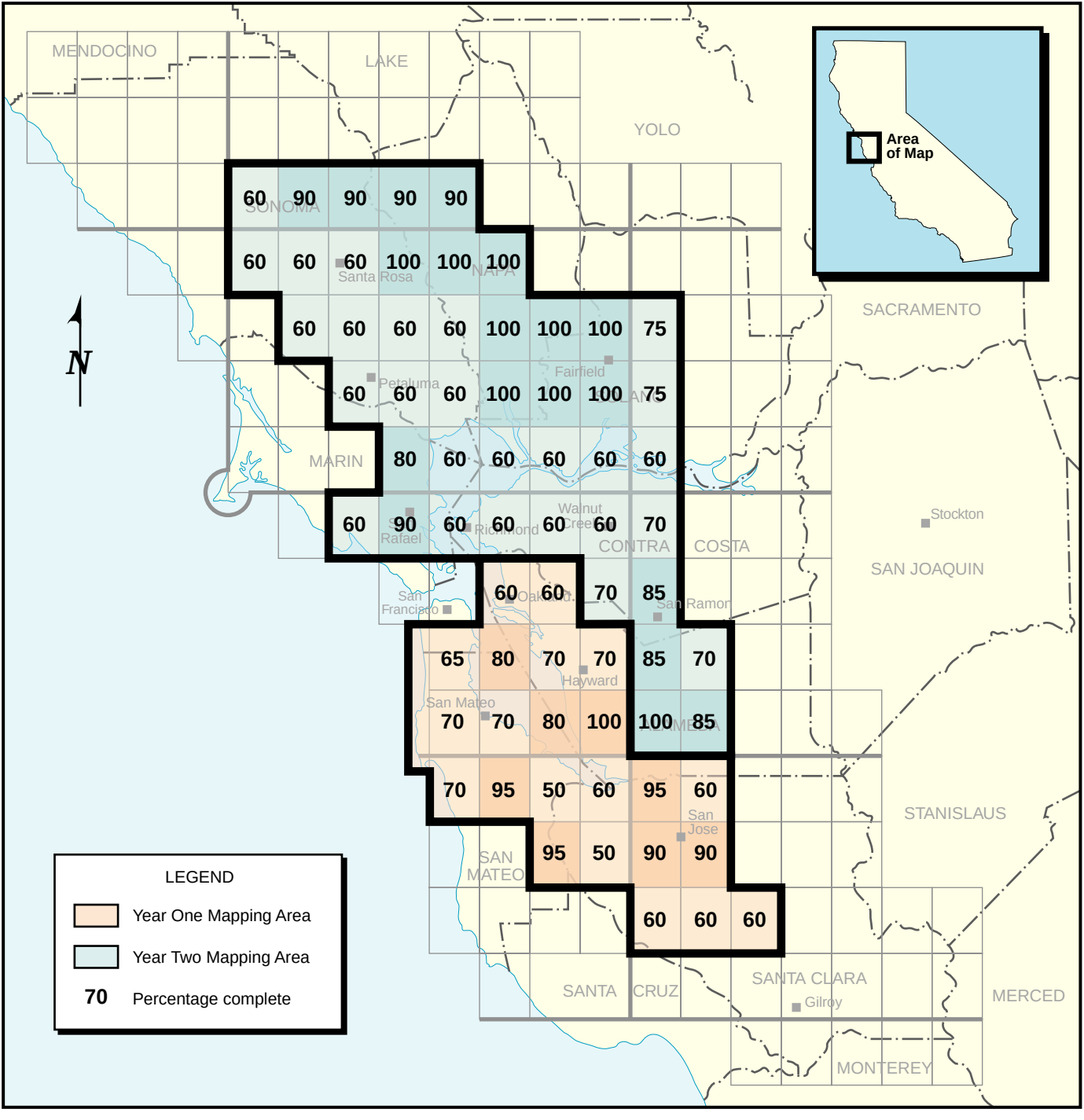

Figure 1. Map showing nine-county San Francisco Bay Area and percentage of Quaternary geologic mapping completed for each quadrangle. Darker shade indicates maps that are 80% or greater complete.

earlier smaller-scale mapping projects by: (1) compiling additional existing or new mapping that was not utilized in our earlier mapping efforts; (2) performing aerial photograph interpretation; (3) performing limited field reconnaissance; (4) finalizing Quaternary geologic maps at 1:24,000 scale; and (5) developing liquefaction susceptibility maps using our Quaternary geologic maps, information on the depth to groundwater, and our past and ongoing geotechnical analyses of the susceptibility of various Quaternary deposits to liquefaction. Our understanding of the liquefaction susceptibility of individual geologic map units will be integrated with the NEHRP study by Hitchcock and Helley, in which the thickness and character of Holocene materials in the southern San Francisco Bay area will be characterized.

The geologic and liquefaction susceptibility maps that we produce have served as part of the baseline data from which CDMG develops liquefaction zonation maps (e.g. Hitchcock and others, 1996; Hitchcock and Wills, 1998). We will continue to consult and interact with CDMG to ensure that maps produced through this project are directly applicable in CDMG's zonation process. The proposed maps also will be submitted to the ongoing USGS effort (joint Earthquake Hazards/Geologic Mapping project through Carl Wentworth) for entry into the digital database for the Quaternary geologic map of the San Francisco Bay region and subsequent release by the USGS as a digital geologic map. Development of the proposed Quaternary geologic maps also will provide valuable information to evaluate earthquake effects, and will directly assist in emergency preparedness efforts, mitigation of potential risks, and development planning.

Anticipated products of this project include two maps of each of the sixty-eight quadrangles. The first map will depict the late Quaternary geology, showing Quaternary deposits mapped on the basis of their age and depositional environment. The second map will depict liquefaction susceptibility, based on the physical properties and groundwater conditions associated with each Quaternary unit. The maps will be accompanied by a report that describes the mapping procedures, Quaternary mapping units, and the criteria matrix used to create the liquefaction susceptibility maps.

Results

Efforts in the first year have centered on the Quaternary mapping. First, to ensure that our mapping is consistent and properly documented, we have developed mapping standard and procedures for this project. These procedures reflect our combined experience on other Bay Area mapping projects. All mapping is drawn on mylar sheets registered to the paper quadrangle. This allows the information to be scanned for digitization. Each contact placed on the map is documented by writing a source code or codes along the contact that indicates the primary type of data that was used to draw that contact. Types of data that will be considered include pre-development aerial photography, topographic contours, soil surveys, historical maps of the shoreline, wetlands, and creeks, existing Quaternary mapping, and field reconnaissance. The precision of each line is indicated by the use of a solid line (+/- <200 feet), or dashed line(+/- >200 feet).

Second, we have developed a Quaternary stratigraphy and unit names that can be applied throughout the Bay Area. The development of the stratigraphy has been a work in progress through the several Bay area mapping projects we have conducted. Originally developed in collaboration with Dr. Ed Helley, a few new units recently have been added and the mapping criteria for some units honed.

The progress of our Quaternary geologic mapping is shown graphically on Figure 1. Because of opportunities to cooperate with other WLA projects located in the Year Two area, we elected to work on quadrangles in both the proposed Year Two and Year One

areas. To generalize, quadrangles shown as 50 to 75% complete are those that have been mapped previously either by WLA at the 1:100,000 scale, or by other workers. This mapping needs varying amounts of additional work in order to bring it up to the standards for this project.

Quadrangles shown as 80 to 100% complete are those that have now been mapped to the standards set out for this project. They still may need a small amount of work, or peer review, or digitization in order to be considered 100% complete. This year we concentrated much of our effort in the southeast bay area, including the San Jose East, San Jose West, Milpitas, Niles, Newark, Dublin, Diablo, and La Costa Valley quadrangles. Several of these maps still need peer review and digitization, thus are not yet 100% complete. In the Year Two area, the large block of maps marked 100% were completed earlier at the request of the County of Napa.

Non-technical Summary

Historically, liquefaction-related ground failure has caused extensive earthquake damage in high density population centers in the San Francisco Bay area. This study will identify regions in the Bay area that are susceptible to liquefaction-related ground failure. Through geologic and geotechnical analysis of Quaternary sediments, this study will produce sixty-eight, 1:24,000-scale maps showing areas underlain by sediment that may liquefy during an earthquake. Through a collaborative relationship with the California Division of Mines and Geology, these maps will facilitate the development of liquefaction zonation maps that will be accessible to local governments and urban planners for aid in emergency response planning, mitigation of potential seismicity risks, and realistic development planning. These maps will also contribute to the U.S. Geological Survey's digital database for the Quaternary geologic map of the San Francisco Bay region and subsequent USGS Open-File Report as a digital geologic map.

References

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